Forest Health Protection

Pacific Southwest Region
Northeastern California Shared Service Area

Date: November 24, 2020
File Code: 3420

To: District Ranger, Beckwourth Ranger District, Plumas National Forest

Subject: Evaluation of stand conditions with respect to forest insects and disease within the Bootsole project, Plumas National Forest (FHP Report NE20-02)

At the request of Kristin Winford, District Silviculturist, Beckwourth Ranger District, Danny Cluck, Forest Health Protection Entomologist, conducted a field evaluation of the Bootsole project on September 23, 2020. The objective of this visit was to evaluate current stand conditions, determine the impacts of forest insects and diseases on management objectives and discuss treatment alternatives. Recommendations provided in this report will assist in the formulation of silvicultural prescriptions aimed at reducing stand density, reducing the prevalence of white fir and increasing resiliency to disturbance events such as insect outbreaks, drought and fire. Kristin Winford, Jeff Lees and Eileen Carey participated in the field trip.

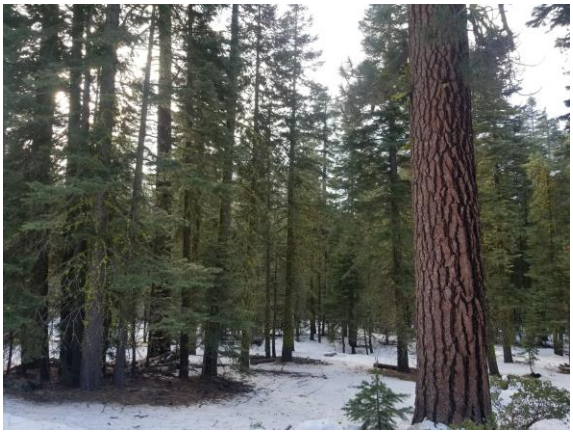

Figure 1. White fir ingrowth in historically pine dominated stand, Bootsole project, 2020

Key findings:

- White fir abundance has increased within the proposed project area due in large part to fire exclusion and is now the dominant conifer species in many stands that were historically dominated by fire-adapted Jeffrey pine (Figure 1).
- Several native forest insects and diseases were found throughout the project area contributing to tree mortality including bark beetles, dwarf mistletoe and root disease.
- Overstocking is putting many stands at risk to high levels of bark beetle-caused tree

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mortality during periods of drought.

- Many stands have experienced high levels of white fir mortality during current and recent drought periods.
- Dwarf mistletoe infection levels are high in some Jeffrey pine stands reducing tree vigor and predisposing trees to bark and woodboring beetle attacks.
- High fuel loading, consisting of dead-down trees and a dense understory of live trees have put many stands at risk to stand replacing wildfire.
- Aspen stands are heavily encroached by conifers
- All stands, except for aspen, should be managed for the pine component. Without a major effort to reduce the abundance of white fir, periodic outbreaks of fir engraver beetle in response to drought will continue to contribute to excessive fuel loading and ultimately result in stand replacing wildfire.

Thinning and prescribed fire are proposed throughout the project area to reduce stocking levels, reduce surface and ladder fuels and change forest composition to favor more drought tolerant species. Specific recommendations are provided in this evaluation.

Description of the project area

The Bootsole project is located approximately 5 miles southeast of Janesville, CA at elevations ranging between 6,080 and 6,600 feet (40.213397N and 120.546594W). Annual precipitation ranges between 20 and 30 inches (Figure 2). Most of the upland areas are a mix of Jeffrey pine (*Pinus jeffreyi*) and white fir (*Abies concolor*) with ponderosa pine (*Pinus ponderosa*) and sugar pine (*Pinus lambertiana*) present in a few locations. Riparian stringers are found throughout the project area and consist of lodgepole pine (*Pinus contorta var. murrayana*), quaking aspen (*Populus tremuloides*), white fir, willow (*Salix* sp.) and black cottonwood (*Populus trichocarpa*). Many forested areas are densely stocked, have experienced elevated levels of tree mortality associated with insects, pathogens and drought and contain high numbers of standing and down dead trees.

Management objectives

The Bootsole project proposes to reduce the risk of insect and disease-caused tree mortality and catastrophic wildfire through mechanical thinning. Fuels reduction and maintenance would also be accomplished with mastication, hand cut and pile and prescribed burning (Figure 3). White fir will be removed in favor of retaining other tree species in mixed conifer and Jeffrey pine/white fir stands. The management objectives for aspen stands are to maintain and enhance the existing aspen cover by increasing light and provide additional growing space for regeneration to reoccupy the historic distribution. Residual stands will be more open, increasing the amount of available soil moisture and sunlight for individual trees.

Forest insect and disease conditions

Heterobasidion root disease (*Heterobasidion occidentalis,* formerly referred to as S-type annosus root disease) was found infecting white fir as indicated by the presence of conks, delaminated

decay on the roots of windthrown snags, stunted leader growth of infected trees and recent mortality associated with the fir engraver beetle (*Scolytus ventralis*) (Figure 4).

Jeffrey pine mortality, caused by western dwarf mistletoe (*Arceuthobium campylopodum*) infections and attacks by California flatheaded borer (*Phaenops californicus*), was observed in a couple of locations. Mortality was older and most dead trees had fallen.

Aspen growing on a drier site at the north end of the project area has been nearly replaced by Jeffrey pine with few overstory trees and mostly dead and downed aspen stems remaining on site. Many of these old stems have evidence of previous sooty-bark canker (*Encoelia pruinosa*) infections and successful attacks from bronze poplar borer (*Agrilus liragus*).

Figure 4. White fir mortality associated with Heterobasidion root disease and fir engraver beetle, Bootsole project, 2017.

Figure 2. Mean annual precipitation for the Bootsole project and surrounding area.

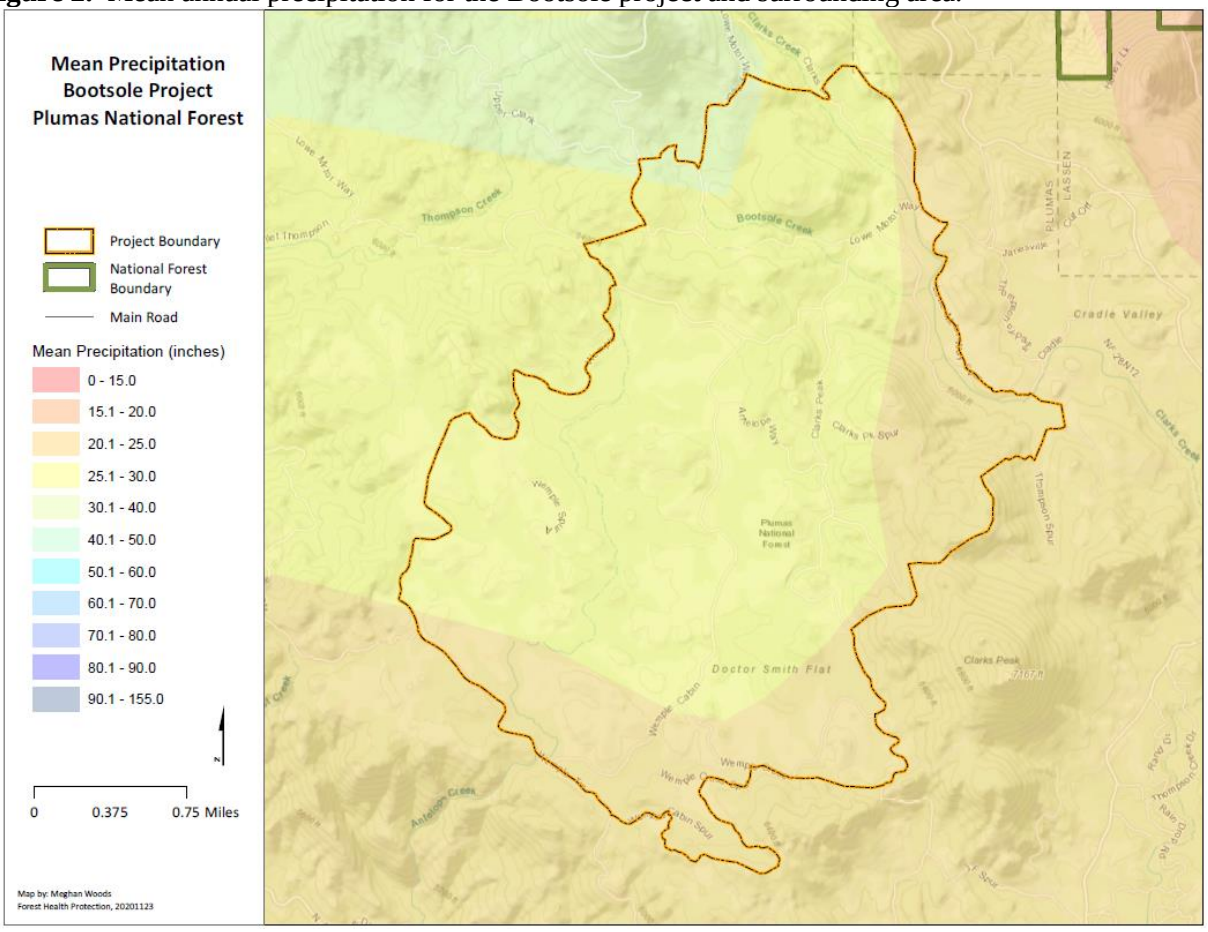
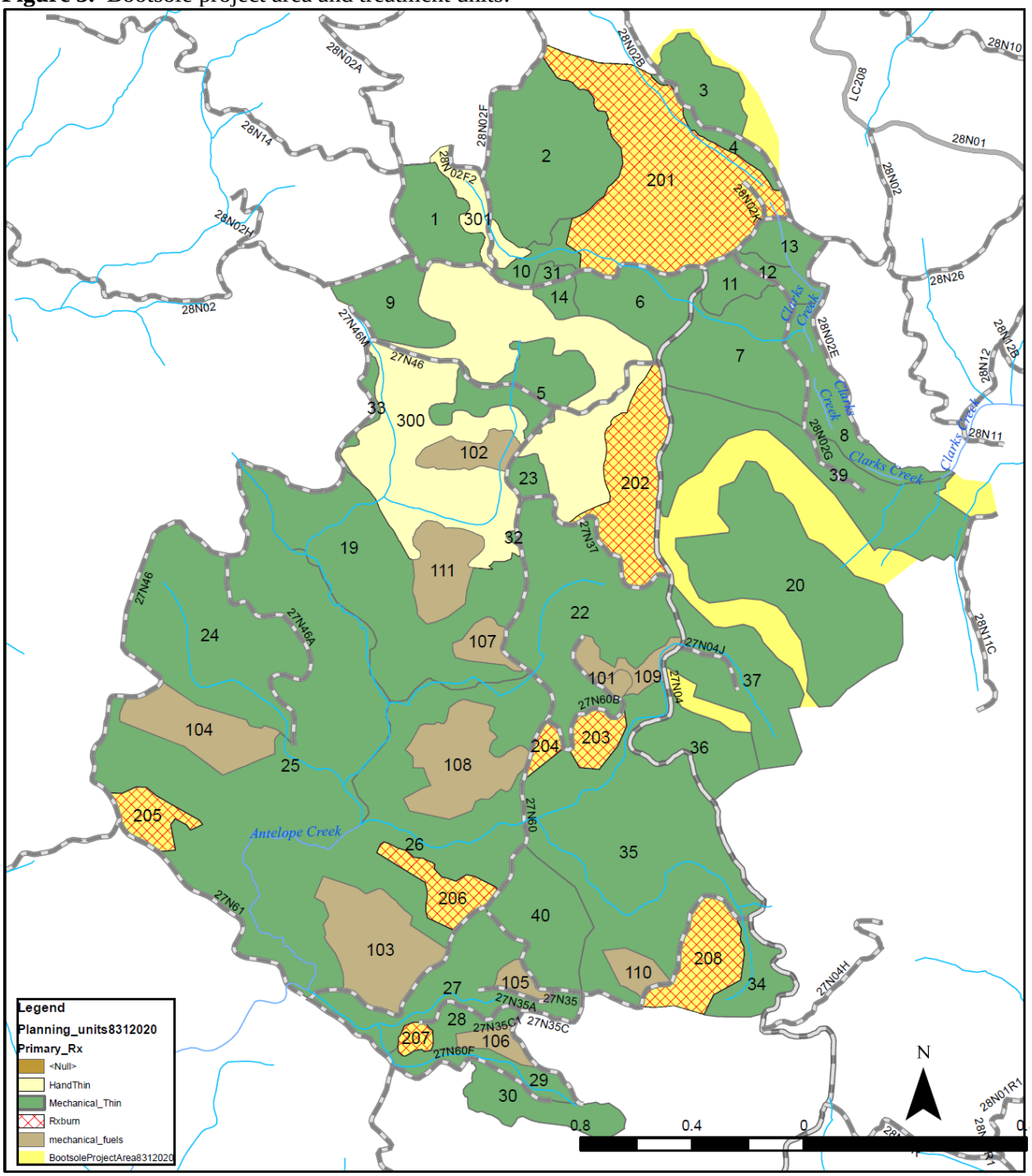


Figure 3. Bootsole project area and treatment units.



Marssonina leaf spot (*Marssonina populi*) was found in a few aspen stands but at greatly reduced levels from recent outbreak years.

Most aspen stands are in a state of decline with decadent overstory trees and suppressed seedlings and saplings due to conifer encroachment.

Stand conditions and mortality related to recent and future climate trends

Many of the stands within the Bootsole project appear to be at or above "normal" stocking levels and have exhibited elevated levels of tree mortality caused by bark beetles during and after periods of drought (Figures 5 and 6, Table 1). This mortality combined with high stand density has resulted in heavy fuel loading in some areas and a corresponding increase in potential fire behavior. Specifically, there are many dead and down white fir throughout the project area that were killed by Heterobasidion root disease and fir engraver beetle during previous droughts.

Tree mortality attributable to insects and/or pathogens is currently at low levels but has been elevated in the recent past (Table 1). This pattern is consistent with many other areas in NE California and the rest of the Sierra Nevada range. Elevated levels of tree mortality are strongly associated with periods of below normal precipitation and high stand density. Successive dry years can exacerbate unhealthy stand conditions, such as those that exist within parts of the Bootsole project area; resulting in higher levels of bark beetle-caused tree mortality. The Palmer Hydrologic Drought Index is also included in Table 1 to show the relationship between drought and tree mortality.

Figure 5. Areas of tree mortality and dead trees per acre mapped by Aerial Detection Survey between 2010 and 2019

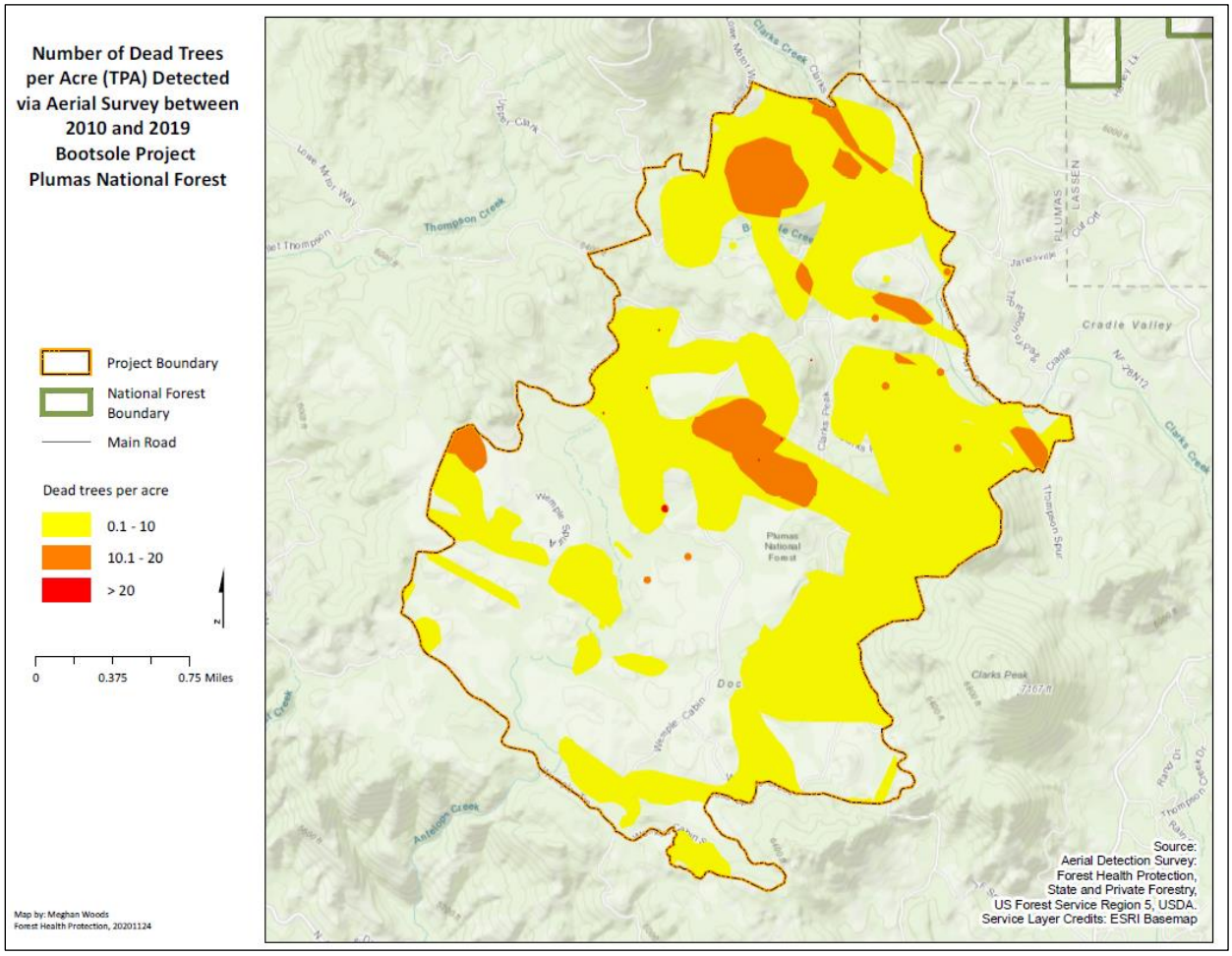


Figure 6. Number of years with elevated tree mortality mapped by Aerial Detection Survey between 2010 and 2019.

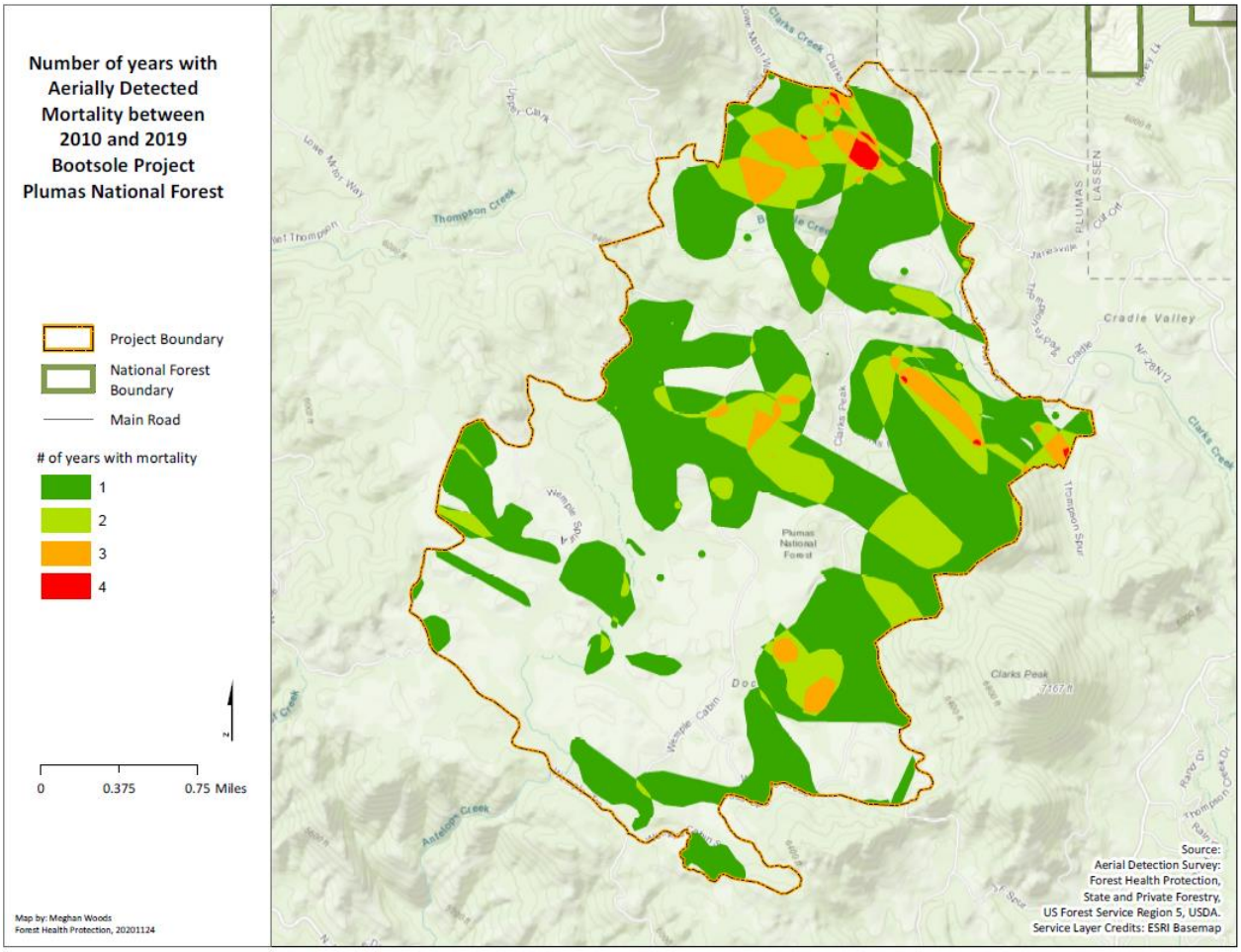


Table 1. Acres with mortality, estimated dead trees per acre and estimated total # of dead trees from R5 Aerial Detection Surveys and Palmer Hydrologic Drought Index (PHDI) (average of CA Divisions 2 and 3[1]) by water year (Oct-Sept) within the Bootsole project area.

Year	Acres	Dead Trees/Acre	Total # of Dead Trees	PHDI[2]
2019	62	6.1	379	0.99
2018	705	2.6	1,808	-0.83
2017	722	6.7	4,815	3.03
2016	201	7.4	1,480	-1.32
2015	49	2.6	125	-3.34
2014	7	1.1	8	-3.56
2013	52	1.0	52	-2.16
2012	135	1.5	196	-0.59
2011	47	0.7	32	2.78
2010	2,174	2.8	6,013	-0.14

[1] California Divisions 2 and 3 encompass most of northeastern California.
[2] PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

Most stands have also experienced a species composition shift from shade intolerant ponderosa and Jeffrey pine to more shade tolerant white fir in the absence of fire (Figure 7). White fir is now abundant on many sites that are considered high to extreme risk for mortality during drought periods (based on average annual precipitation). The mortality resulting from the recent drought as well as previous droughts provides ample proof that these areas do not support healthy stands of white fir over the long-term. In the Bootsole project area, fir engraver beetle-caused tree mortality was most recently elevated from 2016 through 2018 (Table 1).

Figure 7. Remnant old growth Jeffrey pine with white fir understory, Bootsole project, 2017

White fir that succumb to fir engraver beetle attacks are typically predisposed by other factors that compromise their health and vigor. In the Bootsole project area, high stand density, prolonged drought, trees growing off site and Heterobasidion root disease are all contributing factors in declining tree health and mortality.

The distribution of both white fir and white fir mortality are strongly influenced by the mean annual precipitation. The lower limit of precipitation in the natural range of white fir is about 20 inches (Fowels, H.A. 1965). The isohyetal map of mean annual precipitation provided in this report (Figure 1) can be used to rate the risk of white fir mortality (Schultz 1994).

Low risk: 40+ inches annual precipitation **(~0% of Bootsole Project**). These areas easily support stands of white fir. Mortality will be low, even during drought periods. Thinning will increase the rate of tree growth but will show only slight differences in tree mortality.

Medium Risk: 30-40 inches of annual precipitation **(~5% of Bootsole Project**). Stands in these areas often have a high percentage of white fir that may achieve a considerable age and size. Prolonged drought may cause mortality of 5-10% of the stems. Periodic thinning which concentrates on removing white fir ingrowth will lower mortality by maintaining a more sustainable amount of biomass, as well as promoting a more stable mixed species stand.

High Risk: 25-30 inches of annual precipitation **(~60% of Bootsole Project**). In the absence of fire, these areas have stands which are dominated by densely stocked, small diameter white fir. The species distribution by age class shows an increase in the relative percentage of white fir in these stands following fire suppression. Prolonged drought may cause mortality in excess of 50% of the stems. The risk of mortality can be lowered by thinning to a wide spacing prior to the onset of drought, and by promoting a mix of species that are native to the site.

Extreme risk: 20-25 inches of annual precipitation **(~35% of Bootsole Project**). In some cases, the shade tolerant trees may live long enough to achieve an intermediate or co-dominant crown position. Prolonged drought may cause mortality of 80-85% of the stems. In stands where the

total stocking of both overstory and understory is high, mortality may also occur in the pines. The risk of mortality may be lowered by managing groups of pine at wide spacing.

Most of the project area receives less than 30 inches of annual precipitation and no area receives more than 40 inches. Thirty inches is below what is generally required for healthy white fir forests to exist over the long-term. Therefore, even at the lowest stocking levels, white fir growing on these sites are at a high to extreme risk for fir engraver beetle-caused mortality during periods of drought. Even in stands that receive between 30 and 40 inches, the risk of mortality during drought is still considered medium.

A white fir levels of growing stock study conducted by Cochran (1998) on the Deschutes and Fremont National Forests between 1983 and 1995 provides some additional information to consider when managing white fir in lower precipitation areas. Plots were thinned in 1982 and again in 1985 to a residual stand density index (SDI) of 112, 168, 224 or 280. These corresponded to growing stock levels of 20, 30, 40 or 50 percent of normal density. Elevations for his study plots ranged from 4,500 to 5,900 feet with average annual precipitation ranging from 16 to 31 inches. A general drought prevailed over the study areas from the late 1970's to the mid 1990's and mortality between 1991 and 1995 destroyed the study. Mortality on Blocks 2, 3 and 4 of the study was attributed to fir engraver beetles. Mortality from fir engraver beetles appeared to increase with increasing stand densities and was above acceptable levels even at the lowest stand density (20 percent of density considered normal for white fir).

From Cochran 1998:

"Healthy stands of white fir grow very rapidly, produce a dense crown cover, and are visually pleasing. These results, however, raise doubts about growing white fir stands on sites with mean annual precipitation rates below 32 inches even if stand densities are kept very low. The four widely scattered stands represented in this study apparently grew well for more than 60 years and reached commercial size before severe mortality occurred. Where significant amounts of white fir are present, managers need the ability to manipulate stand composition to minimize mortality. Future stands on similar sites should have a large component of ponderosa pine and should be managed by using ponderosa pine stocking guides (Cochran and others 1994). These density levels would allow the individual fir trees, intermingled with pine, to reach commercial size at fairly young ages. If drought, disease outbreaks, or severe insect infestations occur, the white fir could be removed, leaving ponderosa pine on the site. Ponderosa pine quickly responds to new growing space even at old ages and would quickly take advantage of the available site resources. Ferrell (1978) reports that trees under high moisture stress (-20 bars dawn xylem pressure or higher negative pressures) for protracted summer periods are more susceptible to successful fir engraver attacks than are trees under less stress. If prolonged droughts are forecast, removal of most of the white fir on drier sites may be advisable. This would prevent the buildup of fir engraver populations that could migrate to moist sites and inflict heavy damage where, historically, white fir has survived dry periods."

In a Warner Mountain study by Egan et al (2010), the density of fir engraver beetle-caused tree mortality was greater in unthinned versus thinned mixed conifer stands but the percentage of mortality relative to available host trees was similar. This further suggests that white fir growing

in high risk sites (based on average annual precipitation) are susceptible to drought and fir engraver-beetle caused mortality regardless of stocking levels.

From Egan et al (2010):

"Our findings varied in mixed conifer areas as the density of, but not percent, FEN (fir engraver beetle)-caused mortality was reduced in thinned areas. These results do not support the use of thinning to reduce percent mortality or the relative number of residual white fir trees susceptible to FEN-caused mortality during times of drought. Conversely, this study does support the efficacy of thinning to reduce the density of mortality or absolute number of beetle-killed trees in mixed conifer stands exposed to drought conditions. The density of residual white fir host and elevation (likely a proxy for water availability) were important factors associated with white fir mortality in our study. These findings indicate thinning effectiveness in reducing fir mortality was directly proportional to the amount of post-treatment density white fir retained. Thus, our findings support discriminating against residual fir and retaining a greater pine component, similar to historic compositions (Vale, 1977), during thinning treatments to reduce the density of FEN-caused mortality even during periods of drought."

Several Forest Health Protection reports since 1994 have also identified unhealthy white fir stand conditions on northeastern California forests and the need for thinning (FHP reports available upon request). Most of these reports concurred that without treatment, the trend for most stands of increasing stand density, high levels of insect and disease activity and elevated levels of tree mortality would likely continue until a major disturbance event such as a stand replacing fire occurred. Schultz (1994) recommended thinning white fir stands on the Big Valley RD, Modoc NF, to manage for pine as a more sustainable stand structure; stating, "Unless these areas are being managed for habitat for a species which is dependent on small diameter dead white fir, or there is an economic market for small diameter white fir, then it would promote a more sustainable stand structure to manage for pine."

Dense stand conditions and an abundance of white fir appear to have reduced the amount of regeneration of shade intolerant species. The distribution and species composition of old growth trees and stumps remaining within these portions of the project area (mostly Jeffrey pine) suggests that stands were more open in the past, maintained by frequent low severity fire, with fewer white fir.

Predicted climate change is likely to impact trees growing in the Bootsole area over the next 100 years. Although no Plumas National Forest specific climate change models are available at this time, there is a consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (K. Merriam and H. Safford, *A summary of current trends and probable future trends in climate and climate-driven processes in the Sierra Cascade Province, including the Plumas, Modoc, and Lassen National Forests*. The risk of bark beetle-caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant white fir with high levels of disease. Improving the resilience of stands to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested

landscape. Anticipating future drought events and reducing tree density to levels that are more resilient and sustainable should reduce the risk of unacceptable levels of tree mortality within the Bootsole project area.

Considerations for thinning treatments

Most white fir and mixed conifer stands within the Bootsole project should be managed for the pine component as much as possible. This includes all white fir dominated stands with a ponderosa/Jeffrey pine component. This will likely require a change from the current mixed conifer or white fir stand typing in many areas to yellow or eastside pine, better representing historic species compositions and desired future conditions. Having the ability to significantly reduce stand density and the abundance of white fir is critical to successful ecological restoration within the project area.

Thinning stands without significantly reducing stocking levels and the abundance of white fir will not likely result in a change in trajectory towards a pine dominated fire-adapted condition. A high residual component of white fir will continue to produce abundant seed, increasing the number of white fir seedlings relative to pine seedlings. Subsequent and frequent prescribed fire can help change the trajectory of seedling establishment towards pine, but its use is often hampered by lack of appropriate burning conditions, air quality concerns or adequate resources for implementation. Even if prescribed burning is accomplished, is not likely to significantly reduce the number of larger diameter, seed producing white fir in thinned stands due to generally thicker bark and higher crown base heights.

When planning thinning treatments, it should be recognized that the target stand density and species composition is an average to be applied across the landscape and some variability may be desired to increase heterogeneity. Individual high-value trees, such as mature pines, and drier areas dominated by ponderosa/Jeffrey pine should benefit by having the stocking reduced to lower levels. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees. Higher concentrations of white fir can be retained at higher elevations that receive >30" of average annual precipitation or on north facing slopes that receive 25 to 30" of average annual precipitation. Tree removal should include trees heavily infected with dwarf mistletoe, root disease and trees infested with bark beetles. Small group harvest could also be utilized to remove white fir that are within known Heterobasidion root disease centers or are heavily infested with dwarf mistletoe. This would create openings that could be planted with ponderosa and Jeffrey pine. These types of prescriptions would be consistent with 2014 Farm Bill Section 602(d)(1) direction that allows the implementation of projects "….to reduce the risk or extent of, or increase the resilience to, insect or disease infestation in the areas."

In most cases, thinning to a relative density of 25 - 40% (relative to the maximum Stand Density Index, or SDI) for a specific conifer species or for a weighted composition of conifer species will effectively reduce competition for limited water and nutrients and reduce the susceptibility to future bark beetle- caused tree mortality for many years. The latest peer-reviewed research on Jeffrey pine stocking as it relates to Jeffrey pine beetle-caused mortality (Egan et al 2016) and a FHP report for the same study (Egan et al 2009) suggest stocking levels that are at or below SDI

210 (corresponded to < 125 sq.ft./acre of basal area in study plots) to reduce tree mortality during droughts and high bark beetle population pressure. Stocking levels of SDI 110 (corresponded to <80 sq.ft./acre of basal area in study plots) had no Jeffrey pine beetle-caused mortality during the Jeffrey pine beetle outbreak monitored during the study. These stocking guidelines are also appropriate for ponderosa pine (Oliver 1995).

Many stands contain large diameter ponderosa, Jeffrey and sugar pine. Thinning treatments that improve growing conditions for these legacy trees would increase their health and vigor, create opportunities for their successful regeneration and improve overall resiliency to disturbance agents (insects, disease, drought and fire). Removing competing trees from the base of large diameter pines combined with stand level thinning has resulted in a measured increase in annual increment growth in old growth ponderosa and Jeffrey pine on the Lassen National Forest (Hood et al 2017).

The presence of Heterobasidion root disease in white fir, should be considered when developing silvicultural prescriptions. Root diseased white fir are at a higher risk for fir engraver attacks than uninfected trees during droughts. Leaving high numbers of root diseased trees will likely lead to higher levels of mortality over the long-term, reducing large tree canopy cover and increasing fuels. Leaving these trees will also reduce opportunities for successful regeneration of shade intolerant species that are not susceptible hosts to *H. occidentale*.

The best option for managing *H. occidentale* in white fir is to reduce its overall abundance in the stand and remove severely infected trees. Various sized openings can be created in the stand to facilitate planting of non-hosts such as ponderosa, Jeffrey and sugar pine. Placing these openings on known or suspected root disease pockets will enhance the effectiveness of this strategy for reducing overall infection levels. In addition, greatly reducing white fir stocking in stands that have a non-host overstory component will allow for natural non-host regeneration and create a more resilient species composition over time.

It is recommended that a registered borate compound be applied to all freshly cut conifer stumps >14” in diameter to reduce the chance of creating new infection centers of *Heterobasidion irregulare* and *H. occidentale* formerly referred to as P-type and S-type annosus root disease, through harvest activity. An exception to this recommendation would be treating white fir stumps in yellow pine/white fir stands or more pure white fir stands if there is already a high level of Heterobasidion root disease present as treating white fir stumps in heavily infected stands is ineffective.

Effectively managing dwarf mistletoe infection levels within pine stands will require the removal or killing of heavily infected trees. Young ponderosa or Jeffrey pine establishing under an infected overstory will most likely become infected and not reach maturity. It may be desirable to remove or kill infected overstory trees from some areas to allow for healthy stand regeneration (natural or artificial). Removal of all heavily infected trees, especially heavily infected trees in the overstory, combined with general stand thinning will reduce the spread of mistletoe to insignificant levels while increasing the health and vigor of trees with light infections.

It is important when thinning pine stands to be aware of the potential for pine engraver beetle (*Ips pini*) populations to increase in green slash. Ips populations can build up within green pine slash (>4" in diameter) in the spring and successfully attack and kill adjacent pines later in the summer. Mortality to residual pines from *Ips* beetle attacks in California have mostly been associated with green slash in the form of doodle piles or small hand piles that are left scattered throughout the stand near residual trees. The risk of subsequent tree mortality increases with drier than normal conditions and when the green material is longer in length and/or is of a larger diameter that can prevent rapid drying.

Normally, green pine slash, doodles and/or hand piles created from July through early fall (mid-October) will not be conducive to significant Ips population build up. Also, based on past observations of pine engraver beetle activity on the eastside of the Sierra Nevada and Cascade mountain ranges, having pine slash, biomass and sawlogs consolidated into large piles at landings has not resulted in subsequent tree mortality, regardless of timing. If harvest activities are to occur from late fall through early summer (November-June), any green pine material should be removed from the stand, treated (chipping or burning) or consolidated onto landings by the following spring.

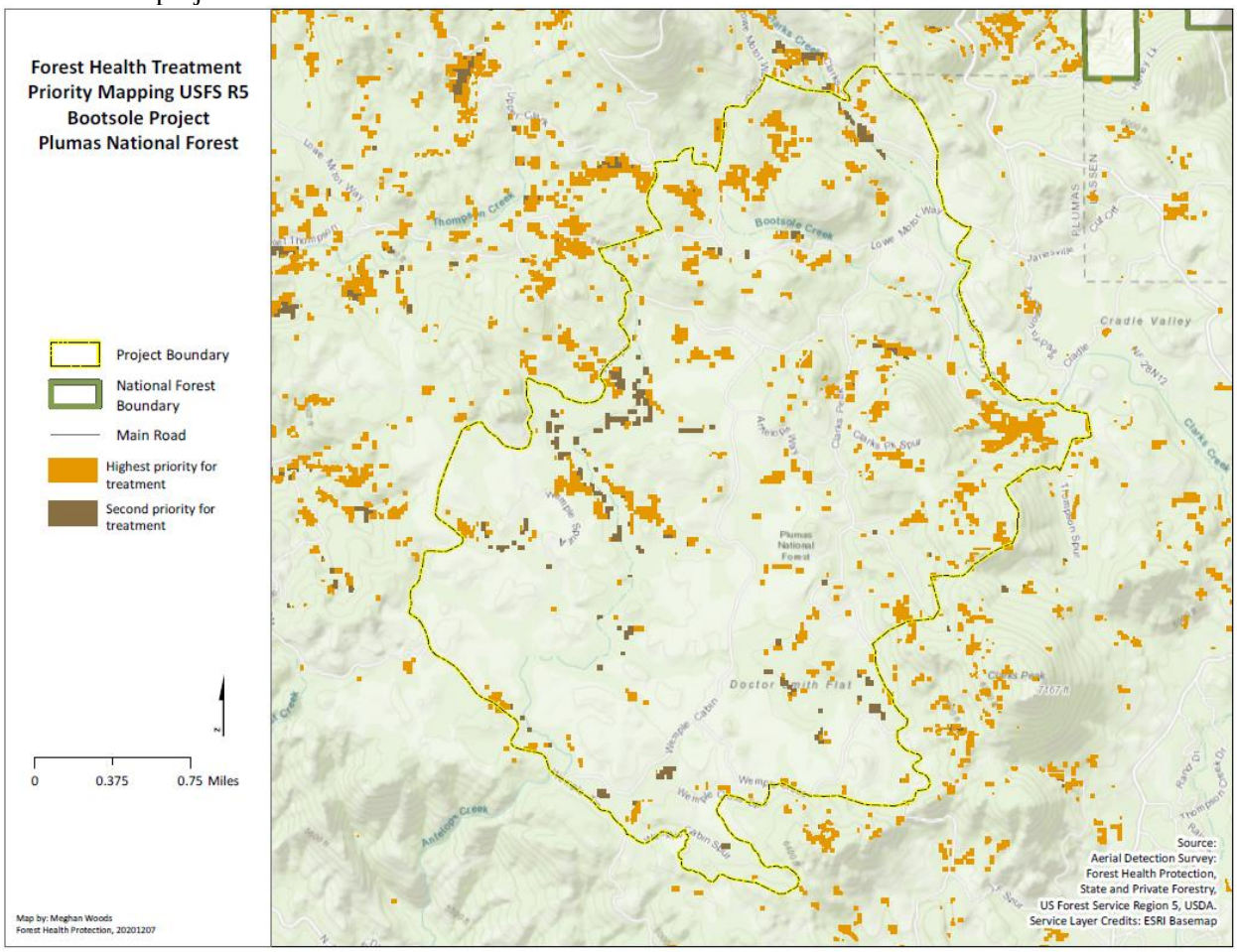
Sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. An exception to this would be thinning suppressed trees within pure sugar pine groups to reduce inter-tree competition. White pine blister rust, a non-native pathogen, has continued to weaken and kill this species over most of its range since its introduction into the Pacific Northwest in 1910. Identification and protection of local rust resistant trees for seed collection, if not already occurring, will aid in the future planting of rust resistant seedlings. Planting selected openings created through thinning operations with rust resistant stock would help ensure this species persists in the area.

Forest Health Protection recently developed a treatment priority map for Region 5 to help land managers prioritize thinning treatments at the landscape level. This map depicts forested areas on National Forest System lands that are the most susceptible to drought and bark beetle-caused tree mortality based on forest type and stand density. These areas also meet the criteria of existing on slopes <=35% and being outside of wilderness areas, wild and scenic river corridors, designated roadless areas and California spotted owl protected activity centers. Additional criteria include not having burned at moderate to high severity since 1998 and not having been thinned since 2005. In addition to being overly dense, these areas have a history of tree mortality during drought resulting in heavy fuel loads and higher risk of stand replacing wildfire. Highest priority areas consist of high-density pine stands, pine-dominated mixed conifer stands, and fir-dominated mixed conifer and white fir stands growing on historically pine dominated sites. Second priority areas consist of high-density fir-dominated mixed conifer and white fir stand on wetter sites. All mapped stands are California Wildlife Habitat Relationship size class 4, 5 and 6.

Figure 10 shows treatment priority areas within the Bootsole project boundary. This mapping effort utilized remotely sensed data to create treatment priority layers for large scale planning and may not be accurate at the stand level. The forest should still use stand records and stand exam data to identify treatment areas and develop silvicultural prescriptions. An ALL LANDS version of the map was also created that includes private land, wilderness areas, wild and scenic

river corridors, designated roadless areas and California spotted owl protected activity centers to evaluate stand conditions in these protected areas. It also includes slopes >35% and all land ownerships (Figure 11). Few of these types of areas are present within the Bootsole project resulting in few additional treatment priority acres mapped for the ALL LANDS version.

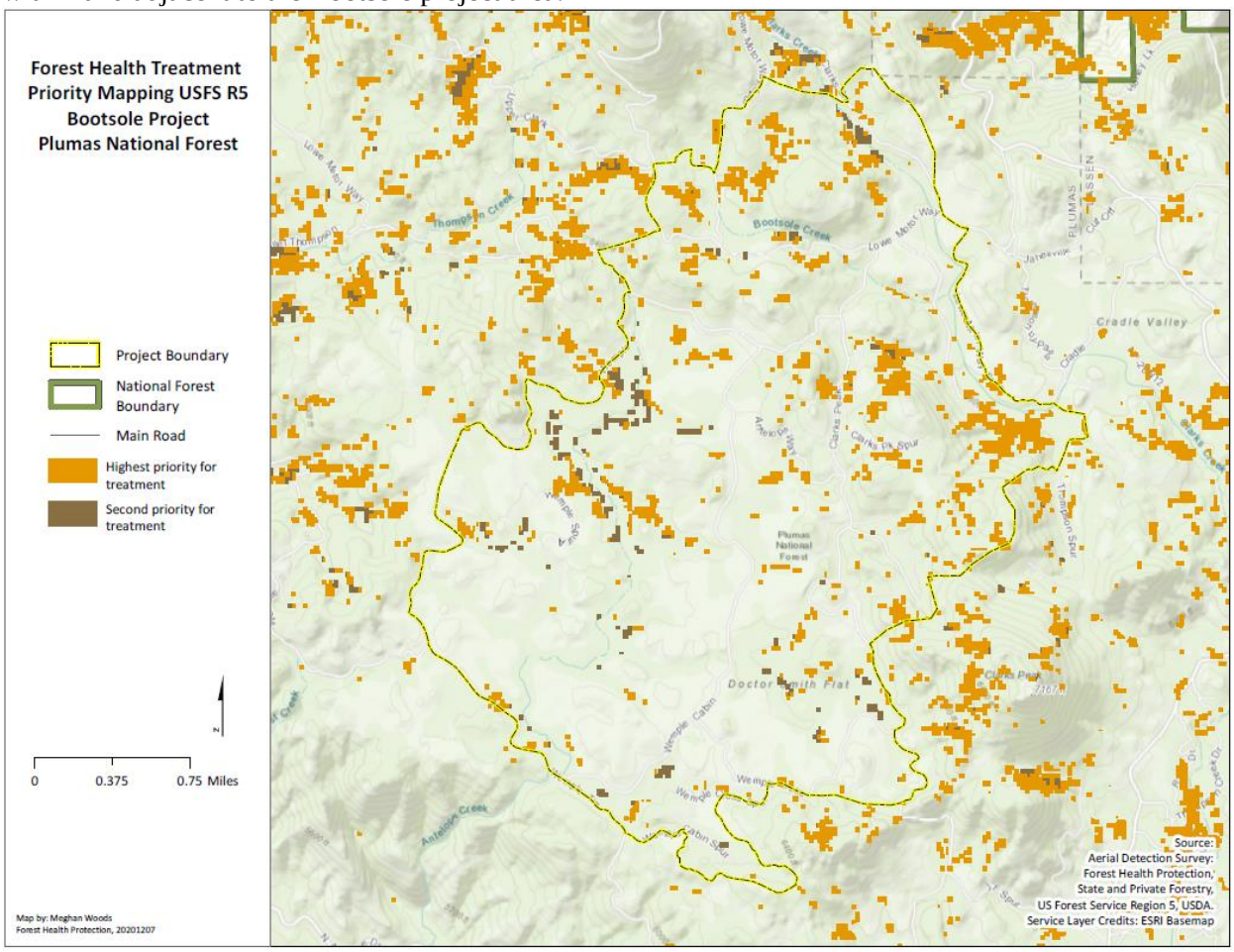
Figure 10. Treatment Priority Areas* at risk to bark beetle-caused tree mortality within and adjacent to the Bootsole project area.


Forest Health Treatment Priority Mapping USFS R5 Bootsole Project Plumas National Forest
Project Boundary
National Forest Boundary
Main Road
Highest priority for treatment
Second priority for treatment
0
0.375
0.75 Miles
Map by: Meghan Woods
Forest Health Protection, 20201207
Source: Aerial Detection Survey: Forest Health Protection, State and Private Forestry, US Forest Service Region 5, USDA. Service Layer Credits: ESRI Basemap

*Highest priority treatment areas include overly dense stands (>60% of maximum stand density index) of pine and pine-dominated mixed conifer stands as well as fir-dominated mixed conifer and white fir stands growing on historically pine-dominated sites. Second priority treatment areas include overly dense stands of fir-dominated mixed conifer and white fir. Mapped areas only include CWHR size class 4, 5 and 6 stands. Wilderness areas, inventoried roadless areas, wild and scenic areas, spotted owl protected activity centers, moderate to high severity burned areas since 1998, areas thinned since 2005, areas with >35% slope and all non-National Forest System lands were excluded from this analysis.

The most recent National Insect and Disease Risk Map (2012) shows many stands within and adjacent to the Bootsole project that are currently at risk to high levels of bark beetle-caused tree mortality (Figure 12). This risk is based on precipitation, stand density and average tree diameter. This version of the map does not incorporate the risk of mortality from diseases such as Heterobasidion root disease and dwarf mistletoes which would increase the number of acres depicted.

Figure 11. Treatment Priority Areas (ALL LANDS version)* at risk to bark beetle-caused tree mortality within and adjacent to the Bootsole project area.

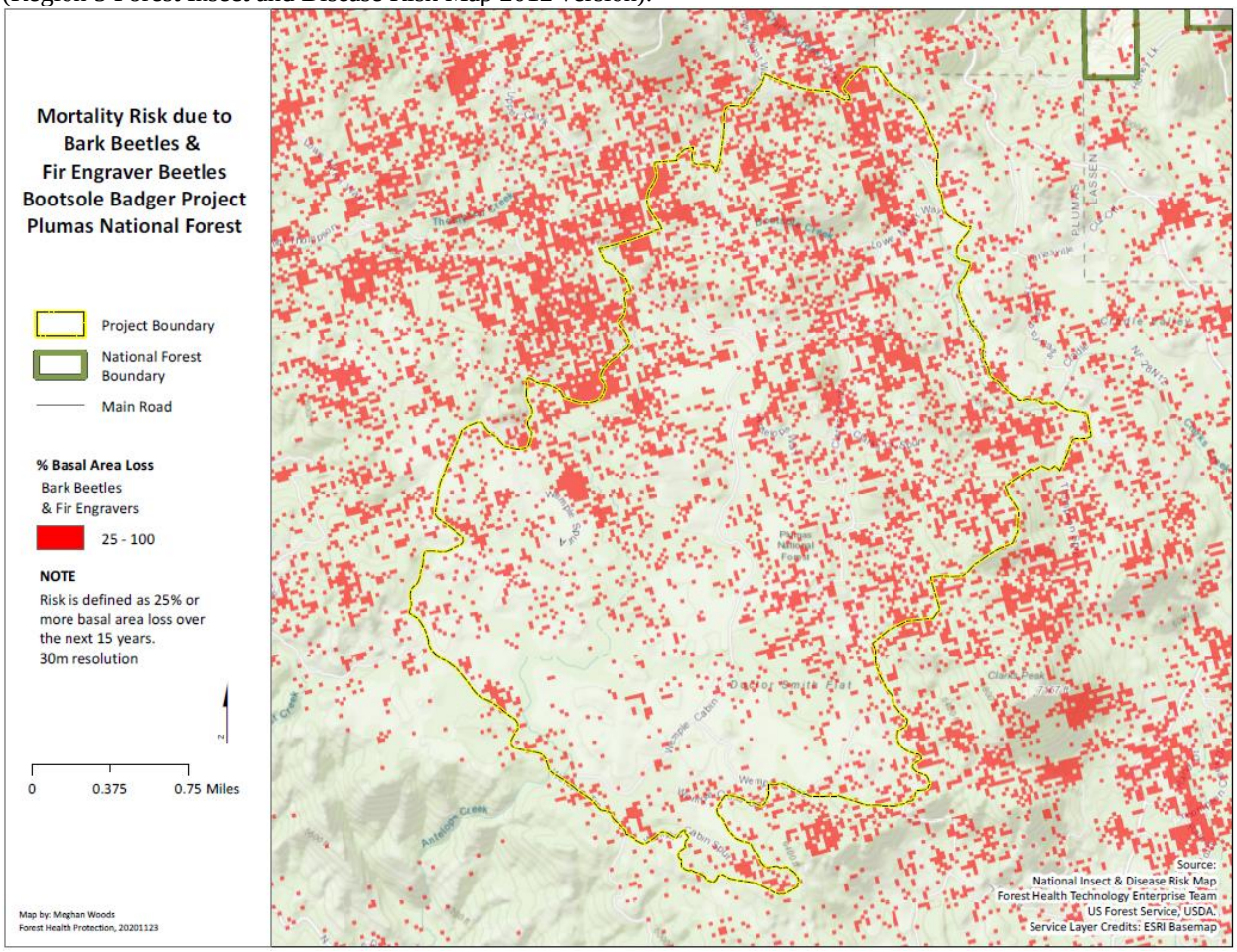


*Highest priority treatment areas for ALL LANDS version include overly dense stands (>60% of maximum stand density index) of pine and pine-dominated mixed conifer stands as well as fir-dominated mixed conifer and white fir stands growing on historically pine-dominated sites. Second priority treatment areas include overly dense stands of fir-dominated mixed conifer and white fir. Mapped areas only include CWHR size class 4, 5 and 6 stands. Moderate to high severity burned areas since 1998, areas thinned or that experienced stand replacing disturbance such as clear cuts or bark beetle-caused tree mortality since 2005 were excluded from this analysis.

Aspen Risk Ratings

Several risk rating criteria have been established for aspen throughout the west. Most of these criteria relate to the abundance of regenerating aspen within a stand, the amount of aspen browsing by wild and domestic ungulates, the condition of the overstory aspen stems and the level of conifer encroachment. Browsing of young aspen combined with conifer encroachment can put an aspen stand at a very high risk of being removed from the landscape. Conifer encroachment and densification often results from the lack of fire disturbance and can eventually shade out aspen stems. Once conifer canopy cover reaches a critical threshold, older aspen stems begin to decline, and regeneration is suppressed.

Figure 12. Risk of bark beetle-caused tree mortality based on precipitation, stand density and average diameter (Region 5 Forest Insect and Disease Risk Map 2012 version).



Conifer cover thresholds that result in elevated risk to aspen stand health vary slightly among regional risk rating systems. However, most risk rating systems describe negative impacts to aspen health beginning when conifer cover reaches 25%. This cover level is not part of a continuum of negative affects but rather a critical threshold where at higher levels aspen abundance declines dramatically. Regional Forest Health Protection aspen surveys categorized percent conifer cover as "severe" when it exceeded 25% (Cluck 2012). 50% conifer canopy cover has been described as the highest risk in some rating systems (Bartos and Campbell 1998). Although these thresholds were established to describe high risk situations, any conifer competition will reduce aspen live crown ratio and basal area increment (Berrill and Dagley 2012).

A conifer canopy threshold of 20% has also been observed above which understory vegetation is highly suppressed (Bobette Jones, Unpublished data, Lassen National Forest). Below this threshold there is an exponential increase in the richness and abundance of understory plant cover. The increase in sunlight and the warming of soils are cited as contributing factors. This 20% threshold is likely relevant to the health and abundance of aspen regeneration.

To maintain and enhance aspen over the long-term, some restoration projects have set post-treatment objectives of 0 - 5% conifer canopy cover or other low levels so as not to exceed 25% within the first 15 years post-treatment (USFS and BLM, CA and NV).

Conifer seed production and regeneration in aspen stands

Conifers within and adjacent to aspen stands provide a seed source that, in the absence of fire, can lead to greater conifer abundance at the expense of aspen. Mature white fir produce abundant amounts of seed and can readily establish within a shaded aspen stand (Pierce and Taylor 2010). Lodgepole pine also produces abundant seed and is moderately shade tolerant. Lodgepole pine regeneration can be especially abundant where ground disturbance from harvest activity has provided bare soil for seed to germinate. Ponderosa and Jeffrey pine are not easily established in shaded areas and generally require disturbance that creates canopy openings and bare mineral soil for seed germination (Forest Effects Information System [FEIS] database).

Treatment alternatives

It is important to consider that aspen communities only make up about 1% of the landscape in northern California. As such, management decisions should emphasize maximizing the benefits for aspen while other objectives, such as the growth and retention of large conifers for wildlife habitat, should be focused in other areas as much as possible. The removal of most conifers that are competing with existing aspen or are in areas where aspen was historically present would maximize the amount of sunlight reaching the forest floor. This will raise soil temperatures and increase photosynthesis allowing aspen suckers to thrive. Buffer areas should be wider at the south end of the stand to further increase the amount of sunlight reaching the forest floor. This type of treatment has proven successful in increasing aspen regeneration in as little as three years post-treatment (Jones et al 2005). The removal of nearly all conifers should reduce the rate of reinvasion and the subsequent need for follow-up treatments to remove conifer regeneration. Conifers that could be retained are ponderosa, sugar or Jeffrey pine >30” dbh and any tree that exhibits old-growth characteristics. This will enhance and maintain the pre-settlement distribution and density of the pine component. Young, post-settlement white fir on good sites can exceed >30” dbh and should be candidates for removal.

Considerations for insects and diseases of aspen

Despite the presence of a few common insect and disease agents, they are impacting aspen health far less than the existing conifer encroachment. While it is important for the District to be aware of the potential for damage by these agents, the impacts of conifer encroachment are a more imminent concern. Once aspen stands are treated by removing conifers and protecting regeneration (if necessary), vigorous stands will be more resilient to the impacts of any native insect or disease.

Considerations for Rx fire

If prescribed fire is used as a follow-up treatment to stand thinning, it may result in unacceptable levels of tree mortality; depending on management objectives. This mortality most often occurs

as a direct result of cambium or crown injury to individual trees during the fire. Mature ponderosa, Jeffrey and especially sugar pines are susceptible to lethal basal cambium damage during prescribed burns from the heat that develops in the deep duff and litter that accumulates at their bases. These duff mounds typically burn at a slow rate with lethal temperatures, causing severe injury to the cambium which girdles the trees. To protect individual high-value large diameter pine from lethal cambium damage, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is recommended.

White fir occurring in nearly pure stands tend to have very high levels of course woody debris on the forest floor as a result of downed logs from self-thinning, the continual shedding of branches and the remaining stems from old stands of brush that have been overtopped and killed by dense fir canopies. These types of stands produce tremendous amounts of heat on the ground surface and often cause severe injuries to the boles and crowns of standing trees, especially to smaller diameter trees. If high post-burn mortality levels in true fir stands, resulting in openings and possibly additional heavy fuel loading, is not an acceptable condition, then fuel treatments such as hand or tractor piling should be considered prior to or in place of prescribed fire. This is especially important in roadside units due to the potential for some fire-injured true fir to deteriorate into an unstable and hazardous condition.

Potential for funding thought the Western Bark Beetle Program

Forest Health Protection may be able to assist with funding, including NEPA activities, for thinning and removing green material from overstocked areas within the Bootsole project area. Thinning treatments that reduce stand density enough to lower the risk to bark beetle-caused mortality would meet the minimum requirements for Western Bark Beetle Program funding and would be supported by this evaluation. If you are interested in this competitive funding please contact me for assistance in developing and submitting a proposal.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

/s/ Danny Cluck

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Insect and Disease Information

Jeffrey pine beetle

The Jeffrey pine beetle is the principle bark beetle found attacking Jeffrey pine, which is its only host. It is a native insect occurring from southwestern Oregon southward through California and western Nevada to northern Mexico. The beetle normally breeds in slow-growing, stressed trees. The beetles prefer trees which are large, mature, and occur singly rather than in groups. Yet when an epidemic occurs, the beetle may attack and kill groups of trees greater than 8 inches in diameter, regardless of age or vigor. Often the beetle infests lightning-struck or wind-thrown trees, but does not breed in slash.

Evidence of Attack

Presence of the beetle is usually detected when the foliage changes color. The color change of the foliage is related to the destruction of the cambium layer by the beetle. Generally, the top of the crown begins to fade in a slow sequence, with the needles turning from greenish yellow, to sorrel, and finally to reddish brown. By the time the tree is reddish brown, the beetles have usually abandoned the tree. Another sign of beetle attack is large, reddish pitch tubes projecting from the bark of the infested tree. If examined carefully, pitch tubes can be detected on infested green trees prior to crown fade. Jeffrey pine beetles have a distinctive "J" shape egg gallery pattern on the inner bark. Larval mines extend across the grain and end in open, oval-shaped pupal cells.

Life Stages and Development

The Jeffrey pine beetle is one of the larger pine bark beetles in California. The beetle has a 4 life stages, egg, larva, pupa, and adult. The adults are stout, cylindrical, black, and approximately five-sixteenths of an inch long when mature. The egg is oval and pearly-white. The larva is white, legless, and has a yellow head. The pupa is also white but is slightly smaller than the mature larva. The life cycle is normally completed in one year in the northern part of the range, but in the southern part, two generations per year may occur. The principle period of attack is in June and July, but attacks also are frequent in late September and early October. Similar to other *Dendroctonus* species, Jeffrey pine beetles use pheromones that attract other beetles to a tree, causing a mass attack that tends to overcome the tree's natural resistance. Blue stain fungi are associated with Jeffrey pine beetle attacks and aid in overcoming the tree's defenses.

Conditions Affecting Outbreaks

Normally the Jeffrey pine beetle is kept in check by its natural enemies, climatic factors and the resistance of its host. Similar to other *Dendroctonus* species, the availability of suitable host material is a key factor influencing outbreaks. Healthy trees ordinarily produce abundant amounts of resin, which pitches out attacking beetles. When deprived of moisture, or stressed by other factors such as disease or fire injury, trees cannot produce sufficient resin flow and become susceptible to successful beetle attacks

Western Pine Beetle

The western pine beetle, *Dendroctonus brevicomis*, has been intensivly studied and has proven to be an important factor in the ecology and management of ponderosa pine thoughout the range of the host species (Miller and Keen 1960). This insect breeds in the main bole of living ponderosa pine larger than about 8 inches DBH. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latidude and elevation, there can be from one to four generations per year.

Evidence of Attack
Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes are formed on the tree trunk around the entry holes. Successful pitch tubes are red-brown masses of resin and boring dust. Relativly few, widely scattered white pitch tubes usually indicate that the attacks were not successful and that the tree should survive. Pheremones released during a successful attack attract other conspecifics. Attracted beetles may then spill over into nearby apparently healthy trees and overwhelm the tree with sheer numbers.

Life Stages and Development
These beetles pass thorugh the egg, larval, pupal and adult stages during a life cycle that varies in length dependent primarily on temperature. Adults bore a sinuous gallery pattern in the phloem and the female lays eggs in niches along the sides of the gallery. The larvae are small white grubs that first feed in the phloem then mine into the middle bark where they complete most of their development. Bluestain fungi inoculates the tree during successful attacks, blocking trachids and vessicles which contribute to the rapid tree mortality associated with bark beetle attacks.

Conditions affecting Outbreaks
Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the Westsince 1899 (Hopkins 1899; cited in Miller and Keen 1960). An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles.Information from surveys conducted in the 1930's indicated enormous losses attributed to the western pine beetle around that time. During the 1930's outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor (Miller and Keen 1960). Group kills do not typically continue to increase in size though successive beetle generation as is typical with Mountain Pine Beetle and Jeffreay Pine Beetle. Rather, observations indicate that emerging beetles tend to leave the group kill area to initiate new attacks elsewhere.

The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing western pine beetle outbreaks. When healthy trees undergo a sudden and sever moisture stress populations of western pine beetle are likely to increase. Healthy trees ordinarily produce abundant resin, which pitch out attacking beetles, but when deprived of moisture, stressed trees cannot produce enough resin to resist the attack. Any condition that results in excessive demand for moisture, such as inter-tree completion, competing vegetation, or protracted drought periods; or any condition that reduces the ability of the roots to supply water to the tree, such as mechanical damage, root disease or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers, predacious beetles, and low temperatures act as natural control agents when beetle populations are low (endemic populations).

Fir Engraver

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater that 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack
Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development
In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks
Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Heterobasidion Root Disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees

presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentale* (also called the 'S' type) and *H. irregulare* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregulare* ('P' type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* ('S' type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf mistletoe

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread

has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

White pine blister rust

White pine blister rust is caused by *Cronartium ribicola* an obligate parasite that attacks 5-needled pines and several species of *Ribes* spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on *Ribes* spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to *Ribes* spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other *Ribes* spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on *Ribes* spp. leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to *Ribes* spp., its spread from *Ribes* spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.

California Flatheaded Borer

The California flatheaded borer, *Phaenops californica*, principally attacks Jeffrey and ponderosa pines, although it may be found in other pines.

It is most severe in stands located on sites where environmental stress is common. Decadent or unhealthy trees are most frequently attacked, along with an occasional top of a thrifty, vigorous tree.

Eggs are laid in bark crevices of the host tree. Newly hatched larvae penetrate directly through the bark to the phloem. Here the larvae may feed from a few months to 4 years without any apparent effect on the host tree. Should host vigor and larval abundance not allow them to succeed, the larvae cut very short galleries before they die. These galleries do not seriously injure the tree and are overgrown by the cambium. Should conditions be, or become, favorable for the larvae and unfavorable for the tree, the larvae develop rapidly and destroy the cambium.

Although this insect can kill trees weakened by dwarf mistletoe and root disease, its primary importance is rendering trees increasingly susceptible to bark beetles.